A STUDY OF THE ABILITY TO DETERMINE TRUE VERTICAL

by

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INTRODUCTION

Military aviation today is of necessity striving to develop and improve its equipment design and personnel training to the point where it may term itself an around-the-clock, all-weather operation. It will achieve this objective only if the present techniques of instrument or "blind" flying are exploited to the fullest measure.

Stated very simply, flying is the maintenance of the proper equilibrium and orientation with reference to the earth. The individual's ability to maintain equilibrium and orientation depends upon sensations received from the eyes, the vestibular organ, and the proprioceptive indicators in the muscles, tendons, viscera, and the skin senses. A whole organism will use any and all cues appropriate to the particular situation. If a person who intends to sit down maintains his equilibrium and orientation, he sits down. If he has lost his equilibrium and orientation, he will very probably fall down. This may be embarrassing but rarely of serious nature. On the other hand, a pilot who has lost his orientation may intend to make a turn to the left and end up in a spin to the right with tragic consequences.

When a person is standing, he maintains his equilibrium and orientation by means of the visual, vestibular, and postural systems, and if any one of these senses is lost, then he must depend entirely upon the remaining system or systems. In the

main, it is agreed that the determinants of spatial orientation are of visual and postural origin. Asch and Witkins (1948) indicate that visual cues are the primary means of spatial orientation and it is true that a blind folded person finds it next to impossible to walk a straight line. In instrument flying, all outside visual references that would normally aid the pilot in aligning the vertical axis of the aircraft with gravitational vertical are lost.

The maintenance of equilibrium and orientation in flight is altered in one important respect from the same functions on the ground, in that ground affords a stationary platform or fixed reference, whereas the aircraft introduces a movable platform which may rotate in the three dimensions of space. The forces affecting the senses are acceleration, centrifugal force and gravity. On the ground, these forces very seldom create erroneous impressions, but during flight and particularly during instrument flight the various cues may be overwhelmingly confusing. Flying personnel recognize that when the normal visual framework or its representative on the instrument panel is absent it is possible to assume many unusual flight positions without perceiving the changes in attitude of the aircraft. During flight it is impossible for the postural senses to distinguish between the sensations caused by the pull of gravity and the sensation caused by centrifugal force. The vestibular organ cannot adequately detect small forces of acceleration and deceleration. A slow entry into a turn, less than two degrees

per second, may not disturb the otoliths enough to stimulate the vestibular sense, while a rapid recovery from a turn produces sufficient stimulation to cause the sensation of entry into a turn, opposite in direction to the initial turn. During well co-ordinated, sustained turns the postural and vestibular senses cannot differentiate between turning and normal "straight" and "level" flight.

Aviators have long been aware that certain situations tend to induce sensory experiences which are not in accord with the objectively correct environmental facts. Any such misapprehension of reality is called "aviator vertigo". Vinacke (1947) found that practically all of a group of aviators interviewed had experienced vertigo on occasions and that forty per cent had experienced vertigo during straight and level flight. Investigators reporting in this field attribute the sensation of vertigo to a variety of conflicting sensations. Burtt (1918) found that the more rapid the inclination from the gravitational vertical in the absence of a visual field, the more exact is the determination of the magnitude of tilt. The reverse is also held to be true; thus, the more slowly the inclination from gravitational vertical the less exact will be the determination of the magnitude of tilt. With postural cues operating alone, deviation from "straight and level" flight often is not detected as a result of adaptation or inadequate stimulation. Passey and Guedry (1949) stated that investigators had indicated that backward tilt or climb was reported in turns in which no climb was

accomplished but only rate of turn was increased. These are a few of a number of conditions which may lead to vertigo.

In instrument flight, the fact that sensory illusions are normal sensations of motion and are experienced by normal individuals should be remembered. Practically all illusions may be sufficiently and successfully suppressed by accepting with confidence the visual perceptions from the instruments so that proper spatical orientation may be maintained.

Experimental research was conducted for this thesis for the purpose of obtaining more knowledge about the senses which interact to maintain our spatial orientation. More specifically, the research was concerned with the ability of the individual to determine true vertical in the absence of the normal visual, kinesthetic, and vestibular cues while body position was varied in two planes. The influence of two types of artificial horizons or blind flying instruments was studied.

Three hypotheses were introduced in this investigation:

I. In the absence of the normal cues which direct spatial orientation, the perception of the vertical in a lateral plane by means of a vertical line will be more accurate than the judgment of the vertical from a horizontal line.

II. In the absence of the normal cues which direct spatial orientation, the judgment of the vertical in a medial plane by means of a horizontal line, as utilized in the instrument used in experiment III, will be more accurate than the judgment of the vertical from the instrument utilized in experiment II.

III. The performance of an individual on the Spatial Relations Test, D. A. T., Form A, may be used to predict the efficiency of the individual to perceive the true position of his body in space by means of artificial visual cues.

METHODS AND MATERIALS

A "swinging" chair, data sheets, a tachistoscope, the D. A. T. Spatial Relations Test, Form A, and two types of artificial horizons were the materials used in the experiments. The swinging chair, data sheets and the artificial horizons are displayed in the Appendix.

The subjects were male college students between twenty and twenty-six years of age. None of the subjects was aware of any physical disability which might affect his equilibrium. Subjects with colds or undergoing medication were not used. The subjects were told only that the experiments concerned one aspect of instrument flying. They were not given any information concerning their own localizing responses or the localizing responses of others.

The two sessions required for the experiments were scheduled to allow five to eight days between sessions. The subjects were asked not to discuss the experiment with anyone during the interim period. At the first session the Spatial Relations Test, Form A, was administered and the subject was placed in eight different positions and asked to indicate the

vertical by means of a rod similar to the control "stick" of an aircraft. During the second period, the subjects were placed in the same positions in space, given specialized visual cues and again asked to indicate the true vertical. This same procedure was rigidly followed in every case.

The "swinging" chair was designed to tilt the body in a medial plane, forward or backward, and at the same time, in a lateral plane to the left or to the right.

An effort was made to void, as far as possible, all kinesthetic, vestibular, and visual cues which might have given the subject some clue as to his body position. Kinesthetic cues were voided as far as possible by constructing the seat so it would be a close fit for the average sized individual. Safety straps were used to immobilize the trunk and the seat was padded. In addition, the foot rest was so placed that the subject's back was firmly positioned against the back of the seat and the legs were lifted with the knees bent so that almost the entire amount of body weight was positioned on the buttocks with little supported by the legs. In this case, the reasoning was that the subjects would not feel the small increments of shifting body weight caused by the change of positions in space. In order to void cues from the vestibular organ, the point in space about which the body was to be rotated was located as near as possible to the vestibular organ so that stimulation of the proprioceptors within the organ would be held to a minimum. The distance

from this point to the mean position of the vestibular organs of the subjects was five and one-fourth inches. Visual cues were voided by conducting the experiment in a totally darkened room.

The procedures for Experiments I, II, and III that follow are the same. Estimates of the vertical were made in each of the eight positions: body tilted forward fifteen degrees, right and left lateral tilt fifteen degrees; forward thirty degrees, right and left lateral tilt thirty degrees; back fifteen degrees, right and left lateral tilt fifteen degrees; back thirty degrees, right and left lateral tilt thirty degrees.

Procedure for Experiment I

Before the subjects were taken into the room which contained the "swinging" chair, they were told that they were to be seated in a chair which could tilt fore and aft and also to either side. The subjects were told that their job would be to position a rod, spring balanced in four directions, at the angle which they felt to be vertical to the floor of the room in which the experiment was conducted.

Prior to swinging the chair to each of the eight positions, the chair was displaced from level fifteen degrees in the opposite direction both in the medial and the lateral planes. An effort was made by the experimenter to move the chair from level to preliminary position at a different rate of speed than the chair

was moved from the preliminary position to the final position. This plus the fact that one-half of the time the final position was thirty degrees or twice the magnitude of the preliminary displacement. The purpose of this preliminary movement was to modify or destroy any mental set or "anchorages" (Koffka, 1922) by which the individual maintained his conceived spatial framework. In each spatial position, a period of ten seconds was allowed to elapse before the subject was asked to move the rod to a position vertical to the floor of the room. When the subject had indicated that the rod was positioned to his satisfaction, readings were taken by the experimenter of the errors in both lateral and medial planes. The errors were recorded in mils (one degree equals 17.78 mils) from displacement of a plumb line. Mils were used instead of degrees so that a more accurate estimate of the rod's position might be made. Goggles covered with black zipatome paper were used to maintain blackout conditions while the experimenter read mil errors.

The Spatial Relations Test, Form A, was administered after the subject had completed the control trials in the chair. Twenty-five minutes were allowed for the test and the answers were recorded on perfo-score answer sheets.

Procedure for Experiment II

Experiment II was conducted after the interim period. Before the subjects were taken into the room which contained

the "swinging" chair, they were shown and had explained to them a representation of the face of the artificial horizon which is in use in modern aircraft at the present time. They were told that this representation of the flight indicator was translucent and that it would be illuminated from the rear by a tachistoscope which could be set for varying timed exposures. The subjects were told of the "rotary" eye motion used by pilots to check all the instruments used in instrument flying. They were told that the experimenter would approximate this instrument checking for them by lighting the representation of the flight indicator for a period of one second then five seconds later, again light it for one second.

The same preliminary fifteen degree opposite movement used before moving the subjects to the final position in Experiment I was also used in Experiment II. Again, a ten second delay between the time of arrival at the final position and the first illumination of the flight indicator was provided. Before the tachistoscope was flashed the first time, the experimenter warned the subjects by saying, "Ready, now." After the flight indicator was illuminated for the second time, the subjects were asked to indicate their conception of true vertical by moving the rod to a position where it was vertical to the floor of the room. After the subjects had moved the rod to a "vertical" position, they were asked to lower the goggles over their eyes once again while the experimenter was reading and recording the errors.

Procedure for Experiment III

A rest period of approximately ten minutes was taken by all subjects after Experiment II was completed. Before the subjects were again taken into the experimental room, they were shown and had explained to them a representation of the face of the experimental flight indicator which was to be used in the third experiment. Again, they were told that it was translucent and that it would be illuminated from the rear by a tachistoscope. The subjects were reminded of the "rotary" eye motion used in checking instruments during instrument conditions. They were told that again the experimenter would approximate this instrument checking for them by lighting the representation of the flight indicator for a period of one second then, five seconds later, again light it for one second.

The same preliminary fifteen degree opposite movement used in the first two experiments was employed again in Experiment III. Again, a ten second delay between the time of arrival at the final position and the first illumination of the experimental flight indicator was provided. Before the tachistoscope was flashed for the first time, the experimenter warned the subjects by saying, "Ready, now." After the flight indicator was illuminated for the second time, the subjects were asked to indicate their conception of true vertical by moving the rod to a position where it was vertical to the floor of the room. After the subjects had moved the rod to a "vertical" position, they

were asked to lower the goggles over their eyes once again while the experimenter was reading and recording the errors. The subjects' eyes were covered only during the time the experimenter read and recorded the data in both Experiments II and III after each of the eight trials in each experiment.

RESULTS OF EXPERIMENT I

Experiment I was designed to be used as a control situation, a departure point, so to speak, against which the results of Experiments II and III were measured. It is significant to note that of the two hundred and forty different responses in Experiment I only four of the lateral responses were overestimations and only nine of the two hundred and forty medial responses were overestimations. In the lateral plane, they ranged from +1.92 degrees to -52.27 degrees. In the medial plane, the range was from +2.08 degrees to -36.41 degrees. This wide range of errors reflects considerable individual differences in the extent of the ability to maintain a frame of reference utilizing the spatial structure; for example, horizontal and vertical lines of the room before it was darkened.

The experimenter's previous contact with flying personnel caused him to question whether or not there would be a difference in responses between being tilted to the right and being tilted to the left. On numerous occasions, the experimenter heard statements such as, "I prefer turning right", or "I would

rather turn left" and a variety of reasons was always given with "It feels better" heading the list.

The F test of the variance between left and right tilt showed that medial tilt apparently had no effect on the difference between the left and the right lateral errors at the fifteen degree magnitude. As shown in Table 2, there is a significant difference between left and right errors with direction of medial tilt apparently having no effect and this difference is significant at the .01 level of confidence with errors to the left having greater variance. The data suggested the possibility that handedness might be a factor to be considered but, unfortunately, all subjects were right handed so no treatment could be devised to evaluate individual differences on that basis. The F test of the variance between left and right tilt at a magnitude of thirty degrees showed no significant difference between the groups. The above cited data would seem to partially support those pilots who "felt" a more "comfortable" direction to turn.

Bartlett's test for homogeneity of variance (Edwards, 1950) showed that for the fifteen degree tilt positions (tilt fore, right and left; tilt aft, right and left) there was nonhomogeneous variance of the position as was expected since the F test applied to the same data resulted in rejection of the hypothesis of random sampling. It was found, however, that by placing left tilt positions together, two homogeneous groups could be obtained.

Table 1. Mean errors in establishing vertical in terms of degrees.

Positions	Experiment I*		Experiment II**		Experiment III***	
	Medial	Lateral	Medial	Lateral	Medial	Lateral
Dorsal left 15	8.64	4.92	4.03	2.20	3.85	.83
Dorsal right 15	8.10	3.92	3.60	2.05	3.70	.95
Vertical left 15	8.48	5.27	3.36	2.20	3.50	1.03
Vertical right 15	7.29	3.55	3.44	1.96	3.74	1.14
Dorsal left 30	6.02	5.78	4.61	3.97	4.01	.97
Dorsal right 30	6.49	5.93	4.85	3.76	4.19	.93
Vertical left 30	6.88	5.53	5.35	5.42	5.42	.92
Vertical right 30	6.90	6.40	5.19	3.07	5.03	.85

* 5.4% of all responses in Experiment I were overestimations.
** 8.7% of all responses in Experiment II were overestimations.
*** 17.1% of all responses in Experiment III were overestimations.

Table 2. Analysis of lateral variances.[1]

Position	F	Greater variance
IV15 Left & Right	18.45**	Left
IV30 Left & Right	2.97	Left
ID15 Left & Right	15.58**	Left
ID30 Left & Right	.192	Right
IIVL15, IIIVL15	10.27**	Expt. II
IIVR15, IIIVR1r	13.06**	Expt. II
IIDL15, IIIDL15	6.62*	Expt. II
IIDR15, IIIDR15	14.9**	Expt. II
IIVL30, IIIVL30	4.35*	Expt. II
IIVR30, IIIVR30	8.4**	Expt. II
IIDL30, IIIDL30	6.72*	Expt. II
IIDR30, IIIDR30	9.41**	Expt. II

* .05 level of confidence D Dorsal tilt, medial plane
** .01 level of confidence L Left tilt, lateral plane
V Ventral tilt, medial plane R Right tilt, lateral plane

1 Lateral variance between all positions in Experiment I and all positions in Experiments II and III were at the .01 level of confidence with Experiment I being greater variance. Therefore, the F's are not displayed.

Bartlett's test suggests further proof that the difference between left and right tilt are not due to random sampling but rather that the experimental conditions have produced significant differences in the means of the right-left tilt groups.

The F test showed no significant variance between right-left tilt groups when the magnitude of tilt was thirty degrees.

Table 3. Analysis of medial variances.[1]

Position	F	Greater variance
IV15, ID15	2.99	Dorsal
IV30, ID30	1.67	Dorsal
IV15, IIV15	8.31**	Expt. I
IV30, IIV30	7.87**	Expt. I
ID15, IID15	10.44**	Expt. I
ID30, IID30	8.62**	Expt. I

* .05 level of confidence
** .01 level of confidence
1 Medial variances between Experiment II and Experiment III in all positions were not significant.

RESULTS OF EXPERIMENT II

The F test showed that the lateral differences in variability of the eight positions responded to in Experiment I and the eight positions responded to in Experiment II were significant at the .01 level of confidence. Each position in Experiment I was compared with its twin in Experiment II. It must be concluded that the visual cues introduced by the representation of the artificial horizon were of such power that the subjects

were able to perceive their body positions in space with a much greater degree of efficiency than in Experiment I where an effort was made to void all cues from all sources. In addition, it was found that the hypothesis that the variances of the populations within Experiment II were equal had to be accepted. The medial difference in variability of the eight positions responded to in Experiment I and the eight positions responded to in Experiment II were significant at the .01 level of confidence. Some difficulty was experienced by three subjects in rationalizing medial tilt by use of the horizontal line. The largest error recorded in Experiment II was 12.3 degrees in the medial plane, and one of the three subjects confessing confusion made that response.

Even though the mean errors and the range of errors were significantly reduced, they still were of such magnitude that if errors such as these were allowed to exist during flight, they would constitute a severe flying hazard. Of course, in flight, the errors could be totally removed by gradually reducing the magnitude by trial and error unless orientation were completely lost and opposite correction applied thereby multiplying the error.

RESULTS OF EXPERIMENT III

The F test showed that the lateral differences in variability of the responses to the eight positions in Experiment II and the eight positions responded to in Experiment III were sig-

nificant at the .01 level of confidence. Each position in Experiment II was compared with its twin in Experiment III. Again, a conclusion may be drawn that the visual cues introduced by the representation of the experimental flight indicator utilized in Experiment II were of greater value in aiding the subjects to perceive body position than the visual cues introduced by the representation of the present flight indicator as utilized in Experiment II.

In Experiment III as in Experiment II, it was found that the hypothesis that the populations were of homogeneous nature was accepted. The medial difference in variability of the eight positions responded to in Experiment II and the eight positions responded to in Experiment III were not significant. This was not surprising due to the fact that the two lines of medial reference were not of radically different design. Again, subjects confessed some degree of confusion while attempting to rationalize body position by means of the horizontal line. The small mean errors reported in Experiment III were due to the fact that 17.1 per cent of the responses were overestimation of the body tilt.

Table 4. Intercorrelations among experiments.

	Experiment I	Experiment II	Experiment III
Spatial relations	.029	.36*	.39*
Experiment I		.23	.18
Experiment II			.44*

* .05 level of confidence

DISCUSSION

The primary purpose for this study was the comparison of the relative value of the existing flight indicator and the experimental flight indicator.

For lateral positions considered individually, the results obtained by use of the experimental flight indicator showed significantly smaller deviation from true vertical than did the results obtained in Experiment II by use of the existing flight indicator. In the light of these findings, the experimenter accepted the hypothesis I that in the absence of the perception of the vertical in a lateral plane by means of a vertical line will be more accurate than the judgment of the vertical from a horizontal line.

For medial positions considered individually, the results obtained by use of the experimental flight indicator failed to show significant differences from the results obtained in Experiment II by use of the existing flight indicator. Because of these findings, the experimenter rejected hypothesis II that in the absence of the normal cues which direct spatial orientation, the judgment of the vertical in a medial plane by means of a horizontal line, as utilized in the instrument used in Experiment III will be more accurate than the judgment of the vertical from the instrument utilized in Experiment II.

Hypothesis III. The performance of an individual on the Spatial Relations Test, Form A, may be used to predict the ef-

ficiency of the individual in perceiving the true position of his body in space by means of artificial visual cues. This hypothesis was accepted with the reservation that the correlation coefficients, being low, should be mechanically improved upon by the use of some device such as the Taylor-Russell Tables. In these tables, a reduction of the selection ratio is a substitute for high validity.

Suggestions for Future Research

The problem of instrument flying at night and under all types of weather conditions, is so vital to the Military Forces of this country that it is imperative that instrument research be of a continuing nature. These experiments tested under flight conditions may serve to produce the more efficient and direct cues necessary to maintain spatial orientation. It was impossible to reproduce all the conditions of instrument flight in this experiment so actually this study was incomplete. These data seem to justify the hope that, when properly reproduced under flight conditions, these experiments will indicate that more accurate lateral orientation may be made by means of responding to a vertical reference line.

The experimenter also believes that study of cause of the left-right tilt variance in Experiment I and the preferred direction of turn would cause investigation and possibly modification of existing Civil Aeronautics Authority instrument flight rules.

SUMMARY

1. Three experiments were conducted to determine the influence of certain factors upon the ability of the individual to locate precisely body position in space.

2. The swinging chair was designed to void cues from the visual, kinesthetic, and vestibular senses. Errors were originally recorded in mils, then transformed into degrees.

3. The visual sense was found to be of prime importance in maintaining orientation and the exactness of orientation is largely due to the design of the substitute cues furnished.

ACKNOWLEDGMENT

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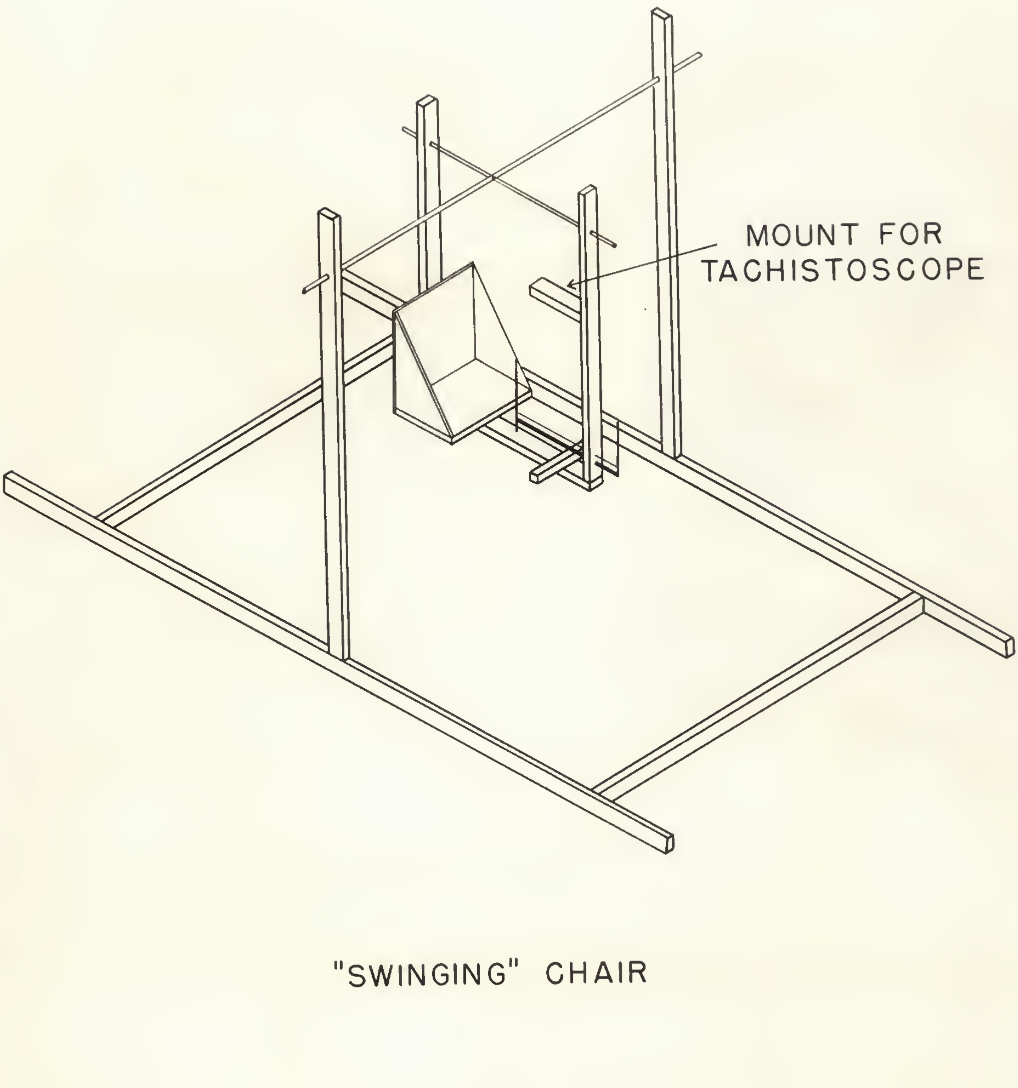
APPENDIX

EXPLANATION OF PLATE I

Design of "swinging chair"

The swinging chair was designed to tilt the body medially fore and aft and at the same time laterally right and left. The apparatus was constructed of two by four inch timber bolted together. The chair rotated around two steel pipes, one two and one-half inches, one one inch. The chair was moved by a system of pulleys reeved with wire cable. The cables operated off a windlass so that movement in both planes could be controlled from the right rear of the subject. The cable was wrapped with wire at points to indicate when the chair was at fifteen degrees or thirty degrees so that the experimenter could operate it in a darkened room. For purposes of illuminating the flight indicator representations, Plate II, a tachistoscope, enclosed in a light proof box, was mounted just below eye level (Handbook of Human Engineering Data). The subjects responded by positioning a rod in what they perceived to be vertical. This rod was swiveled and connected to another rod in front of the chair which repeated exactly the position of the subject's rod. Errors were recorded from the second rod by means of plumb lines and a protractor graduated in mils (degree equals 17.77 mils) so that finer readings than one degree might be arrived at.

PLATE I



"SWINGING" CHAIR

EXPLANATION OF PLATE II

Plate II is made up of the representation of the two types of flight indicators used in Experiments II and III. Figures 1 and 2 are representations of the standard flight indicator in use at the present time. Figures 3 and 4 are representations of the experimental flight indicator.

In Figures 1 and 2, the long yellow bars represent the horizon and the two short yellow bars represent the wings of the aircraft. In Figures 3 and 4, the yellow bars represent the vertical and horizontal axes of the aircraft, while the orange bars represent the true vertical and the position of the horizon relative to the nose of the aircraft.

These instrument representations were lighted by projecting light from the rear, through these figures representing the flight indicator, for measured amounts of time.

PLATE II

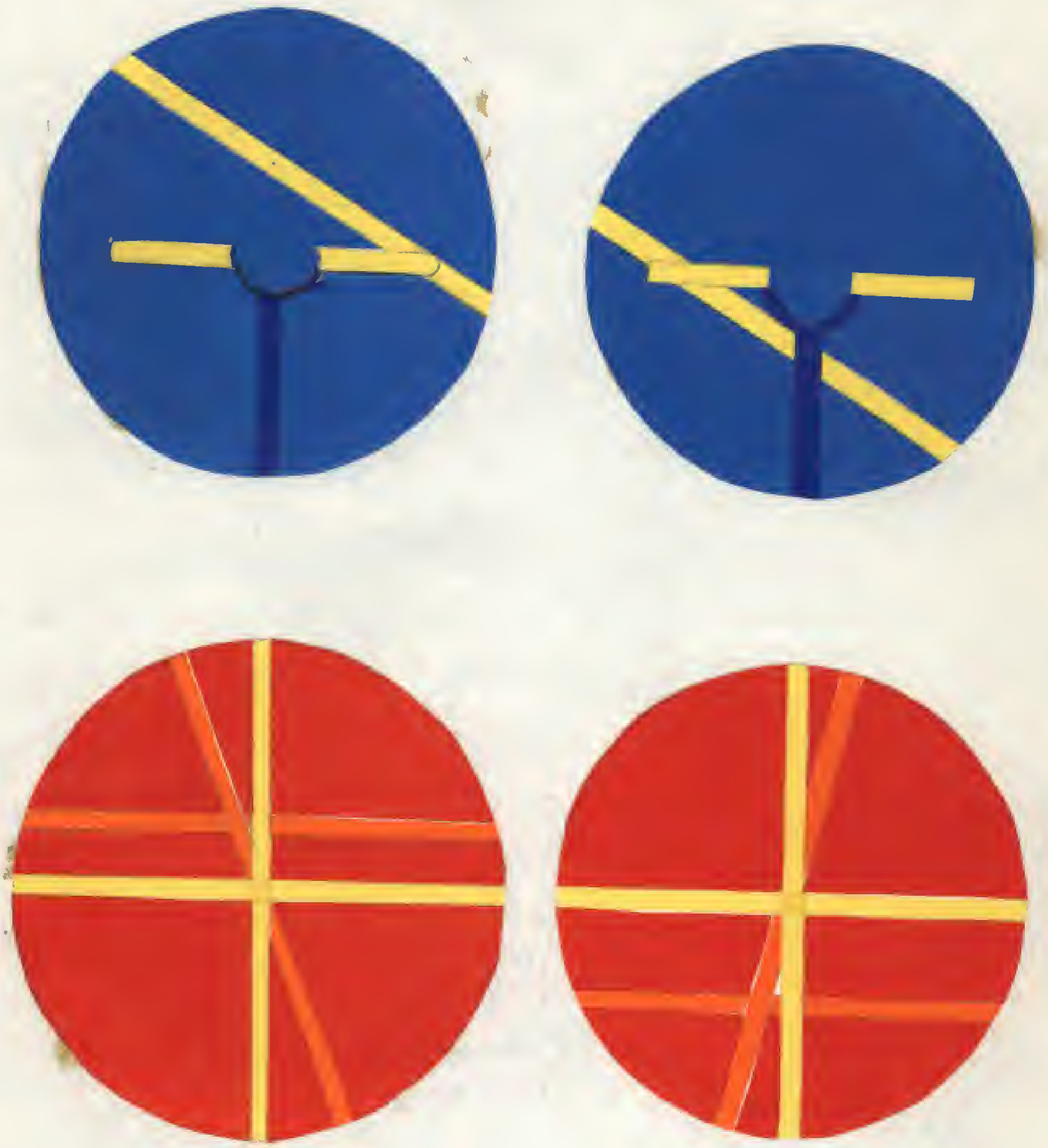


Table I Results of variances.

$F_{.95}$ (1,58) 4.01

$F_{.99}$ (1,58) 7.10

$F_{.95}$ (1,118) 3.92

Conditions	Source of variation	d.f.	Mean square	Ratio
IVR15, IVL15	treatment	1	20311.6	18.45**
	individual	58	1100.8	
IVR15, IIVR15	treatment	1	27520.4	4.33*
	individual	58	6357.8	
IVL15, IIVL15	treatment	1	45553.2	10.79**
	individual	58	4221.8	
IIVR15, IIIVR15	treatment	1	23316.01	13.06*
	individual	58	1785.3	
IIVL15, IIIVL15	treatment	1	12936.1	10.27**
	individual	58	1259.3	
IVL30, IVR30	treatment	1	8472.8	.2115
	individual	58	40051.4	
IVR30, IIVR30	treatment	1	98062.6	5.21*
	individual	58	18822.0	
IVL30, IIVL30	treatment	1	56181.6	7.81**
	individual	58	7195.1	
IIVR30, IIIVR30	treatment	1	12192.6	8.40**
	individual	58	1451.5	
IIVL30, IIIVL30	treatment	1	6140.8	4.35*
	individual	58	1413.9	
IDR15, IDL15	treatment	1	4933.0	15.58**
	individual	58	316.4	
IDR15, IIDR15	treatment	1	26782.0	9.73**
	individual	58	2752.5	
IDL15, IIDL15	treatment	1	5119.0	8.26**
	individual	58	619.7	
IIDR15, IIIDR15	treatment	1	219.0	14.9**
	individual	58	146.7	
IIDL15, IIIDL15	treatment	1	4987.0	6.62*
	individual	58	753.3	
IDL30, IDR30	treatment	1	141.0	
	individual	58	732.79	
IDR30, IIDR30	treatment	1	26544.0	7.39**
	individual	58	3591.3	

Table I (concl.).

Conditions	Source of variation	d.f.	Mean square	Ratio
IDL30, IIDL30	treatment	1	21698.0	7.43**
	individual	58	2920.7	
IIDR30, IIIDR30	treatment	1	8447.0	9.41*
	individual	58	897.7	
IIDL30, IIIDL30	treatment	1	13938.0	6.72*
	individual	58	2074.1	
IV15, ID15	treatment	1	6962.0	
	individual	118	7052.6	
IV30, ID30	treatment	1	1794.0	
	individual	118	2369.0	
IIV15, IID15	treatment	1	9321.6	3.13
	individual	118	2976.4	
IIV30, IID30	treatment	1	15809.5	2.67
	individual	118	5907.3	
IID15, IIID15	treatment	1	249228.7	1.23
	individual	118	201814.7	
IIV15, IIIV15	treatment	1	14732.0	1.65
	individual	118	8931.7	
IID30, IIID30	treatment	1	4791.4	1.49
	individual	118	3210.9	
IIV30, IIIV30	treatment	1	1846.0	
	individual	118	6608.9	

A STUDY OF THE ABILITY TO DETERMINE TRUE VERTICAL

by

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It is essential that military aviation will reach a level, both in personnel training and in instrument design, where it is no longer restricted to flying only during periods of "good" weather when the sun is shining. Military aviation must exploit to the fullest measure all the present techniques of instrument flying.

The primary factor in flying is the continual maintenance of both equilibrium and spatial orientation. The individual's ability to maintain equilibrium and orientation depends upon the sensations received from the visual, vestibular, and kinesthetic senses.

It is no problem to maintain one's equilibrium and orientation on the ground where a stable platform is furnished. It is altogether a different problem when one desires to exercise these faculties and fly. An aircraft introduces a movable platform which may rotate through the three dimensions of space. To further complicate matters, normal forces perform in abnormal ways which tend to induce sensory experiences which are not in accord with objectively correct environmental facts. This situation is known as "Aviators' Vertigo".

During instrument flight, all visual cues to proper equilibrium are hidden and all that is left are the kinesthetic and vestibular systems both of which are highly susceptible to the transmission of sensations that are not objectively correct.

Asch and Witkins (1948) indicate that visual cues are the

primary means of spatial orientation and it is upon the visual system, aided by instrument, that we depend to allow flight during periods of bad weather.

This study was conducted for the purpose of obtaining more knowledge about the senses which interact to maintain our spatial orientation. More specifically, the research was concerned with the ability of the individual to determine true vertical in the absence of the normal visual, kinesthetic, and vestibular cues. A comparison of the relative merits of two types of artificial horizons was made.

There were three hypotheses introduced in this investigation:

I. In the absence of the normal cues which direct spatial orientation, the perception of the vertical in a lateral plane by means of a vertical line will be more accurate than the judgment of the vertical from a horizontal line.

II. In the absence of the normal cues which direct spatial orientation, the judgment of the vertical in a medial plane by means of a horizontal line, as utilized in the instrument used in Experiment III, will be more accurate than the judgment of the vertical from the instrument used in Experiment II.

III. The performance of an individual on the Spatial Relations Test, D. A. T., Form A, may be used to predict the efficiency of the individual to perceive the true position of his body in space by means of artificial visual cues.

During this study, thirty male college students were uti-

lized as subjects. These subjects were moved in the swinging chair to eight different positions in each of the three experiments and their impression of vertical was recorded. Experiment I was a control situation with all cues, visual, vestibular, and kinesthetic, voided to as great a degree as possible. Experiment II was conducted using only those visual cues that might be derived from the flight indicator in use today. Experiment III was conducted using only those visual cues which might be derived from the experimental flight indicator.

The procedures for Experiments I, II, and III were the same. Estimates of the vertical were made in each of the eight positions: body tilted forward fifteen degrees, right and left tilt fifteen degrees; forward thirty degrees, right and left lateral tilt thirty degrees; back fifteen degrees, right and left lateral tilt fifteen degrees; back thirty degrees, right and left lateral tilt thirty degrees.

The results of Experiment I showed that the overwhelming majority of the responses were underestimations of tilt. Only thirteen of the four hundred and eighty responses were overestimations.

One not wholly unexpected feature arose from this experiment, a variance at better than the .01 level of confidence was found between fifteen degrees right and left lateral tilt with the greater error being to the left. It has been suggested that handedness might have some effect. This was not followed up during the experiment.

The results of Experiment II showed that the errors could be drastically reduced by use of the visual cues from the present flight indicator. These cues were of such power that variances between Experiment I and Experiment II were greater than the .01 level of confidence.

The results of Experiment III disclosed that the visual cues were of even greater power than those in Experiment II and further reduced the errors. The variance of all lateral positions was at the .01 level of confidence but no significant differences were found between the medial differences.

Hypothesis I was accepted at better than the .01 level of confidence.

Hypothesis II was rejected.

Hypothesis III was conditionally accepted in spite of low correlation coefficients. Use of the Taylor-Russell Tables would improve selection efficiency.

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